UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2009/2010

November 2009

EBB 512/3 - Phase Diagram and Phase Equilibra

Duration : 3 hours

Please ensure that this examination paper contains TEN printed pages before you begin the examination.

This paper consists of SEVEN questions.

Instruction: Answer **FIVE** questions. If candidate answers more than five questions only the first five questions answered in the answer script would be examined.

The answers to all questions must start on a new page.

All questions must be answered in English.

1. [a] Considering a binary solution containing A and B, show that the heat of formation ΔH^M based on quasi-chemical model is given by

$$\Delta H^M = P_{AB}(E_{AB} - (E_{AA} + E_{AB})/2)$$

Where ΔH^M = enthalpy of mixing
P_{xy} = no.of bonds of each type
E_{xy} = bond energy of each type

State any assumptions made for the derivation.

(10 marks)

[b] Shown in Figure 1 is the diagram of free energy of mixing of liquid and solid solutions of the A-B binary system at temperature T1

(i) Is it true that $T1 < Tm(A)$ and $T1 < Tm(B)$? Tm is the melting point of I.

(ii) The diagram shown occurs when the heat of mixing, HM is positive. Prove that $H^M(\text{solid}) > H^M(\text{liquid})$.

Sketch the expected phase diagram based on the free energy diagram and indicate the stable phases.

(10 marks)

Figure 1

Figure 2

2. Refer Figure 2 Be-W phase diagram for the following questions:

[a] List the composition and temperature of ALL the invariant points, congruent points and what kind of reaction it is.

(6 marks)

[b] For the temperature 2000^{o}C, use the Be-W binary phase diagram to sketch the Gibbs free energy curves as function of at% W needed to make up the phase diagram at this temperature. Be sure to note the important composition points on your graph.

(4 marks)

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[c] Based on the phase diagram, what can you deduce about the elements W and Be relative to one another? Explain your reasoning.

(4 marks)

[d] For the alloy composition of 80at% W, determine the phases present, their compositions and relative amounts, and sketch the microstructure at the following temperatures (i) 2500^{o}C and (ii) 2090^{o}C.

(6 marks)

3. [a] An important structural ceramic is partially stabilized zirconia (PSZ) which has a composition lying in the two-phase ZrO_2-cubic ZrO_2 (ss) region. By referring to Figure 3 calculate the amount of each phase present in a 10 mol% CaO PSZ at 500^{o}C.

(6 marks)

[b] In a test laboratory, quatitative x-ray diffraction determines that a refractory brick has 25 wt% alumina phase and 75 wt% mullite solid solution. What is the overall SiO_2 content (in wt%) of this material. Refer Figure 4 for your answer.

(9 marks)

[c] Briefly explain why a proeutectoid phase forms along austenite grain boundaries

(5 marks)

Figure 3

…6/-

Figure 4

4. [a] Name the two stages involved in the formation of particles of new phases. Briefly describe each.

(6 marks)

[b] A theoretical expression for the rate of pearlite growth from austenite is

$$\acute{R} = Ce^{-Q/RT}(T_E - T)^2$$

where C is a constant. Q is the activation energy for carbon diffusion in austenite, R is the gas constant, and T an absolute temperature below the equilibrium transformation temperature TE. Derive an expression for the temperature TM corresponding to the maximum growth rate, that is the 'knee' of the transformation curve. If TE = 1900K and Q = 42 kJ/mol calculate TM.

(6 marks)

5. [a] In 10 kg of an iron-carbon alloy and at a temperature just below the eutectoid temperature, the mass of total cementite is 0.76 kg. (i) What is the proeutectoid phase in this alloy? Why? (ii) Calculate the mass fraction of pearlite at a temperature just below the eutectoid. Refer Figure 5.

(8 marks)

[b] Briefly describe the phenomenon of coring and why it occurs. Cite one undesirable consequence of coring.

(4 marks)

[c] For an iron-carbon alloy of composition 5 wt% C - 95 wt% Fe, make schematic sketches of the microstructure that would be observed for conditons of very slow cooling at the following temperatures (i) 1175^{o}C (ii) 1145^{o}C and 700^{o}C. Label the phases and indicate their composition. Refer Figure 5.

(8 marks)

Figure 5

6. [a] Explain, with the help of appropriate diagram(s), how a ternary phase diagram is constructed.

(6 marks)

[b] Discuss how a ternary phase diagram is related to the binary phase diagram. When does a ternary phase diagram become useful?

(4 marks)

[c] In relation with the above, elaborate on the following cases. In each case, which phase diagram would the student refers to? And what would be the purpose of using the phase diagram you mentioned (or the result that you will get out of the diagram)?:

(i) A student is doing a research project on the effect of certain alloying elements on a metal (say, effect of adding Cerium, Bi and In to Sn-Ag-Cu solder alloy).

(ii) Another student is studying the optimum heat treatment route to homogenize TiAl-Nb alloys microstructure.

(iii) Another student is trying to fabricate a ceramic body consisting of Forsterite-Anorthite-Silica, and study the effect of different composition on microstructure.

(10 marks)

7. [a] Shown in Figure 6 is the phase diagram of the SiO_2-CaO-Al_2O_3 system*. Discuss solidification paths for the compositions p, q and r indicated on the diagram.

(10 marks)

[b] In the system ABC, a ternary alloy containing 40% B and 8% C undergoes a eutectic reaction L → α + β over a temperature range 550 - 500°C as part of its solidification sequence. The compositions of the phases coexisting in equilibrium at 540°C and 510°C are as follow:

	α	β	L
540°C	85%A, 10%B, 5%C	5%A, 93%B, 2%C	55%A, 30%B, 15%C
510°C	82%A, 11%B, 7%C	6%A, 89%B, 5%C	48%A, 32%B, 20%C

Calculate:

(i) The proportions by weight of α and β phases present in the alloy at 540°C.

(ii) The ratio of the proportions of liquid phase present at 540°C and 510°C.

(10 marks)

Figure 6 - Phase diagram of SiO_2-CaO-Al_2O_3

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APPENDIX 1

APPENDIX 2

APPENDIX 3

APPENDIX 4